PID - The Problem and How to Solve It

Module Regeneration with the PV Offset Box

Content

Potential Induced Degradation (PID) is a phenomenon which affects some PV modules with crystalline Si cells and leads to gradual deterioration of performance, reaching up to 30 percent and more after a few years. Some module manufacturers are already working to develop countermeasures by using new materials, but the general trend to three-phase systems and system voltages up to 1,000 V is currently exacerbating the problem rather than alleviating it. In addition to negative earthing of the PV array, SMA Solar Technology AG now offers a simple technical solution to prevent this reduction in power of PV modules reliably, also when using transformerless inverters. This Technical Information first gives a brief overview of the PID effect and then explains how the PV Offset Box works and when it can be used.

1 Cause: Voltage and Potential to Earth

If we want to understand PID, we must first define the terms voltage and potential: the electric potential of a point describes its voltage compared with a defined reference and zero point. In most cases, this is the earth. By contrast, the term "voltage" describes a difference in potential between random points, i.e. simply the difference between two electric potentials.

Example: If point A has a potential of 380 V to earth and point B has a potential of 430 V, the voltage between A and B is exactly 50 V.

Under nominal conditions, typical PV modules supply approximately 30 V. Connection in series to module strings results in a far higher array voltage. It drives a corresponding direct current which the inverter converts into grid-compliant alternating current. The earthing of the PV array, its potential, is prescribed by the potential of the connected electricity grid and the design of the inverter. Ideally, the positive and negative poles of the PV array should be symmetrical to the potential of the (earthed) neutral conductor. For example, if the MPP voltage of the module string is 400 V, the PV module at the negative end has a potential of – 200 V to earth, while the module at the positive end of the string has a potential of +200 V (see SB with transformer in Figure 1). For some transformerless inverters, it can also be shifted to the negative side. The problem: a positive or negative potential to earth can have unwelcome side-effects depending on the module type - the PID described here is one of them.

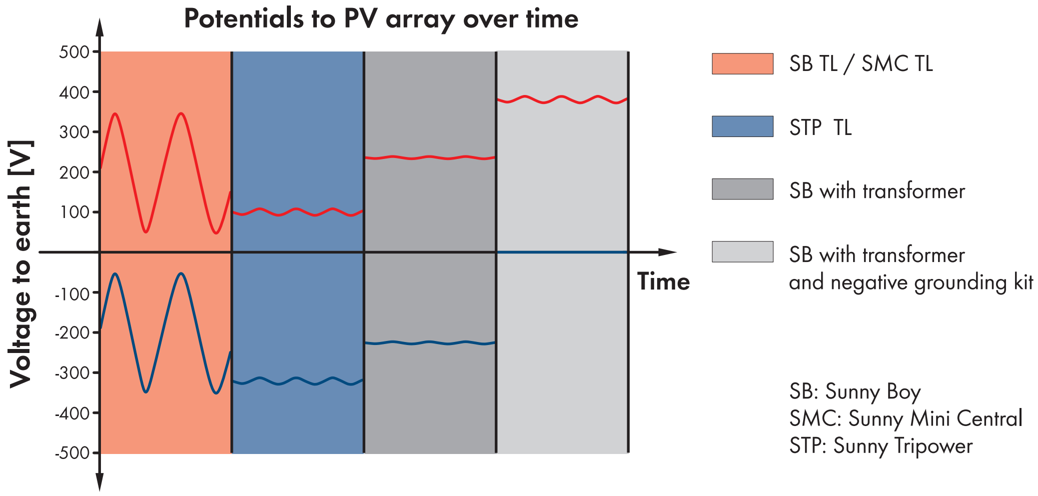

Figure 1: The potential (amount, sign and chronological sequence) of the lowest (blue) or highest (red) PV module within a string depends on the type of inverter used and on whether an array pole is earthed. Example for an MPP voltage of 400 V.

The range and, in particular, the sign of the array potential can only be specified freely if galvanically isolating inverters are used. As they do not feed their power directly to the electricity grid, but via a magnetic coupling, they always allow the PV array to be earthed. As a result, the potential of the entire PV array can be shifted entirely into the positive or negative range. This option is not available for transformerless inverters, as they are connected to the electricity grid with electric conduction, and earthing would cause internal short circuits.

2 What is Potential Induced Degradation (PID)?

The phenomenon described here only occurs in modules with cells made of crystalline silicon. If the modules have a negative potential to earth in operation, there is an equally high negative voltage between the cells of the PV module and the aluminium frame, which is earthed for safety reasons. The effect is stronger, the closer the module is to the negative pole of the PV array, as the potential there (and thus the voltage between cells and the aluminium frame) can reach more than half the amount of the array voltage. As a result, electrons from the materials used in the PV module can separate, follow this electric field and finally flow out via the aluminium frame. The result is an increasing charge (polarisation) of the module, which adversely changes its characteristic curve and thus its power (Figure 2) unless countermeasures are taken.

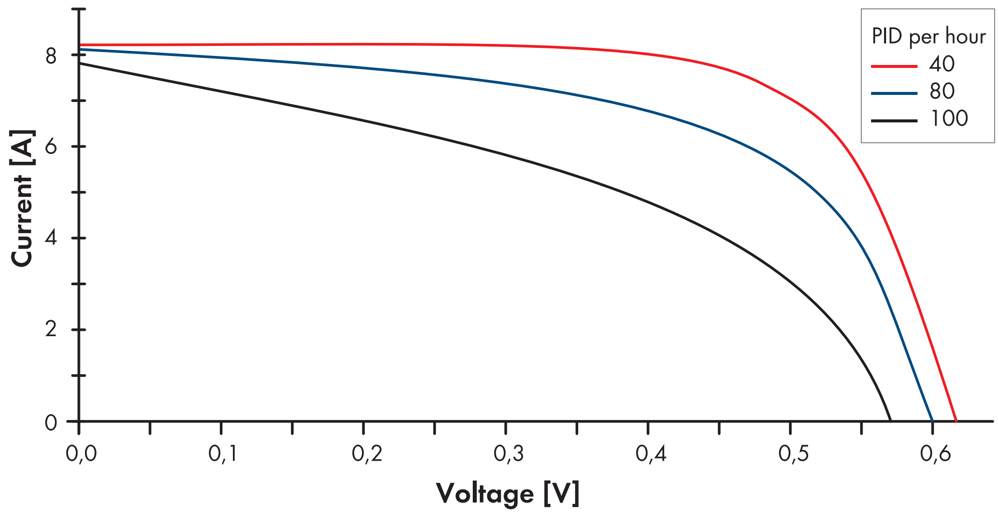

Figure 2: The characteristic curve of a PV module in the original state and during the degradation process A decreasing slope with a virtually unchanged open-circuit voltage and short-circuit current, while the maximum power (MPP) decreases by 30 percent or more, is typical.*

The electric charge of the PV module is so critical because of the way solar cells work. The photovoltaic effect is based on the combination of two different semiconductor materials to establish an internal electric field by exchanging charges. It is this field that causes the electrons freed by light energy to move from their location and flow past the contacts as electric current. Additional load carriers can considerably interfere with this effect, causing a significant loss of power.

However, it has been found that this polarisation can generally be reversed. Accordingly it is not an irreversible effect such as corrosion and normal aging-related deterioration. The term "Potential Induced Degradation"* was first used in the 2010 publication by module manufacturer Solon, which examined the phenomenon in detail.

* J. Berghold et.al, Potential Induced Degradation of solar cells and panels, proceedings of the 25th EU PVSEC, 2010

3 Further Information on PID

In the past, power losses based on PID have been the exception rather than the rule. Recently, however, there are increasing indications that many cell types display this failure pattern, without the manufacturer being aware of it. The abovementioned article by Solon identifies the major influencing factors for PID susceptibility:

- Solar cells: The structure of the PV cells has an influence on the PID via the charge carrier density of the silicon used and the chemical composition of the anti-glare coating.
- PV module: The materials used in the PV module also play a role, for example, the laminating film that comes directly into contact with solar cells (usually EVA).
- System configuration: as described above, the maximum negative potential of the PV modules plays a significant role. This depends on the length of the module strings, the inverter type and possible earthing of the PV array.
- Time: The PID and the resulting power loss are not immediately apparent - they develop over a period of several months to a few years.

4 PV Offset Box as a Solution

In PV plants with galvanically isolating inverters, PID can be prevented reliably by earthing the negative pole of the PV array, as this shifts the potential of the entire PV array to the positive. In PV plants with transformerless inverters which, due to their design principle, are significantly less expensive and more efficient, the required effect can be achieved using the PV Offset Box. The PV Offset Box exploits the fact that the PID effect is reversible and progresses relatively slowly.
How it works: If the array voltage falls below a defined threshold after sunset, the PV Offset Box raises the entire PV array to a high positive potential (between +400 V and +1,000 V to earth), reversing the polarisation effect which occurred in operation (Figure 3). When used on a PV array which has been affected by PID for an extended period, full regeneration of the PV modules takes roughly half as long as degradation. The energy drawn from the household grid is negligible, as the current that flows during regeneration at night is minimal, due to the current restriction in the PV Offset Box ($P_{AC\ nom} < 3$ W).

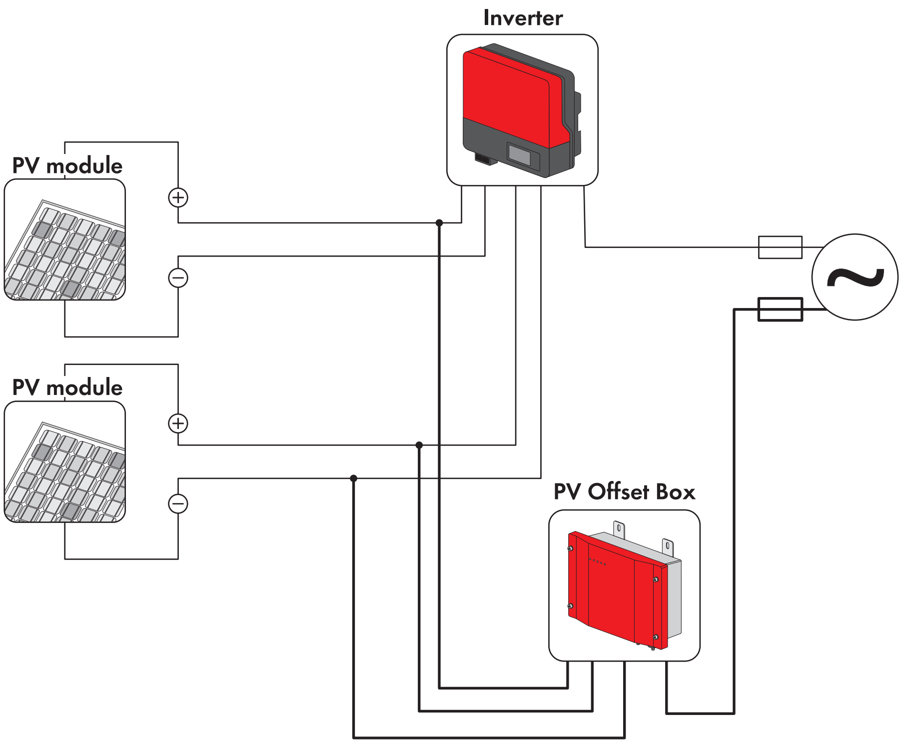

Figure 3: In plants with separately-operated module strings, the PV Offset Box on the array side is connected to a negative pole and the positive poles of the two strings. The regeneration voltage is not applied until the two string voltages reach a defined threshold.

Information: Even if the PV modules are not exposed to higher voltages in the regeneration process than in normal operation, approval of the module manufacturer is required before using the PV Offset Box.

5 Summary of the Advantages

- Permanent and reliable solution of the PID problem
- Greater energy yields thanks to the use of transformerless inverters
- Old plants can easily be retrofitted
- Cost advantages thanks to the use of transformerless inverters
- Cost advantage as no earthing set is required
- Negligible energy consumption
- Compatibility in principle with PV inverters from other manufacturers

Alternatives to using the PV Offset Box:

- Replacing affected PV modules with new PV modules which are not susceptible to PID
- Use of a galvanically isolating inverter and a negative earthing set

6 Requirements for Operating a PV Offset Box

In principle, the SMA PV Offset Box can be combined with any inverter. However, in order to connect the SMA PV Offset Box to a PV plant, approval by both the manufacturer of the PV modules and the inverter manufacturer is required. If necessary, observe additional requirements by the manufacturers.

Depending on the operating mode, the SMA PV Offset Box supplies a fixed output voltage or automatically controls its output voltage. With automatic voltage control, the SMA PV Offset Box automatically complies with the maximum permitted system voltage.

With a fixed output voltage, it may not exceed the maximum DC voltage of the PV modules and the inverter. See the corresponding product documentation for details of the DC voltage of the components in your PV plant. You will find the specific restrictions for operation with the SMA PV Offset Box in the manufacturer approvals for the PV modules and inverters.

7 General Information on the Procedure in the Event of Power and Yield Losses

The PID phenomenon described above only affects some module types with solar cells made of crystalline silicon. It is not to be confused with TCO corrosion, an irreversible process which can occur in some thin-film PV modules, especially in CdTe and a-Si modules (for further information on TCO corrosion, see the Technical Information "Module Technology").

There is also a variety of other causes for yield losses. If this is the case, we urgently recommend that you have an expert examine the PV plant. Plant operators who suspect that their plants are affected by PID are encouraged to contact their module manufacturer through their electrically qualified persons. However, the following signs may provide an indication that the plant is affected by PID:

- The ratio of the MPP voltage to the open-circuit voltage (U_{mpp}/U_0) and the open-circuit voltage U_0 itself have decreased steadily compared with the values specified in the datasheet.
- Parts of the plant equipped with identical PV modules but with different inverters do not show any power output losses. This is particularly the case if these plant parts are operated at another string voltage.

For further clarification, it may be necessary to ask the manufacturer. If they do not expressly emphasise that their modules have been specifically tested and certified PID-resistant, there is usually a certain risk of PID occurring.

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